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EDUCATION AND RECRUITMENT OF OCEANOGRAPHERS IN THE UNITED STATES

A Report by The Committee on Education and Recruitment, The American Society of Limnology and Oceanography, Inc.

AUGUST 30, 1960

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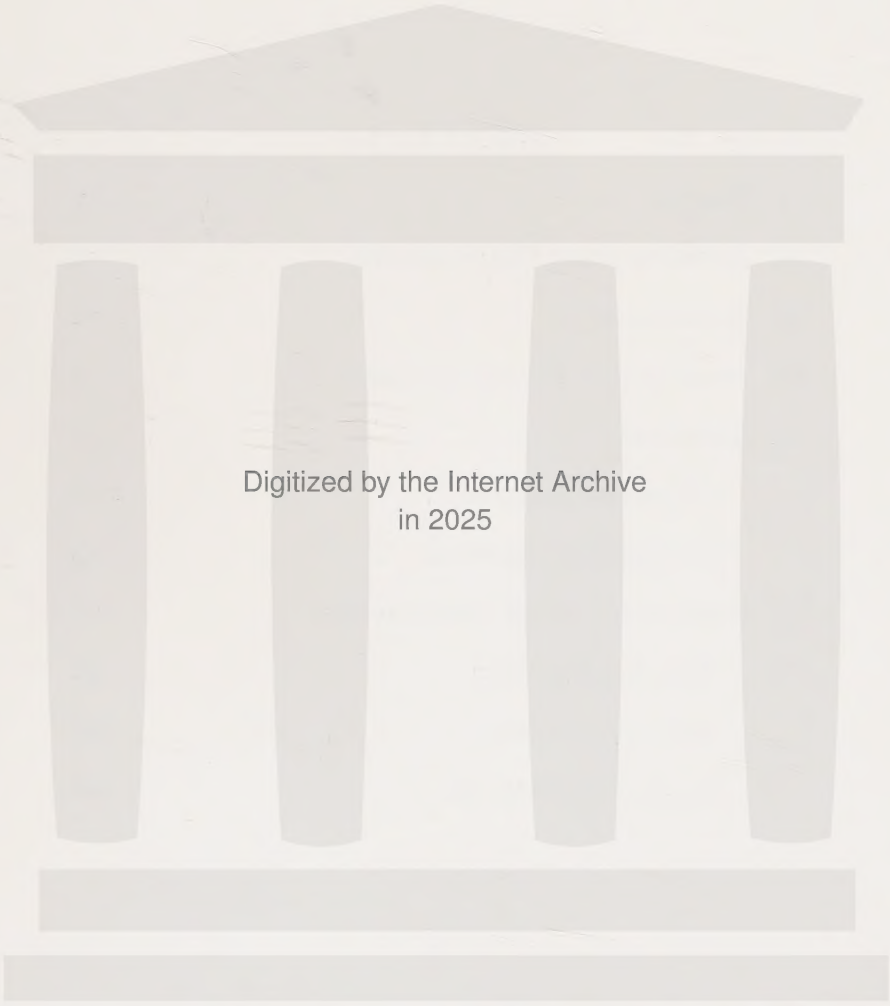
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I. PREFACE

The Committee on Oceanography of the National Academy of Sciences in its report entitled "Oceanography, 1960 to 1970" has recommended that the United States Government expand its support of the marine sciences at a rate which will permit basic research activity, at a minimum, to be doubled during the next ten years. Inasmuch as the recruitment of oceanographers is barely sufficient to meet the requirements of existing research programs, the recommended increase in the support of oceanography may result in a serious shortage of scientific manpower unless an adequate number of students are educated in the marine sciences.

The American Society of Limnology and Oceanography, at its annual meeting on September 1, 1959 adopted a resolution congratulating the Committee on Oceanography on the recognition it has given to the problems and needs of oceanography and concurring in the necessity of expanded programs of research in all disciplines which apply to the basic problems of aquatic science. As the representative organization of a large number of aquatic scientists in responsible academic positions the Society recognized its responsibility in connection with the education of the additional personnel required by the program envisaged. To assist in meeting this responsibility a standing committee on education and recruitment was appointed. This committee herewith submits a report.[1]

Because of the national origin of the problem it has considered, and of the support required for its solution, the committee has limited its discussion to conditions within the United States. Close relations exist between the oceanographers of this and other countries and a free exchange of personnel is maintained between them, in particular with Canada. The committee believes that conditions within the latter country resemble those within the United States so closely that many of its conclusions may be applied appropriately to Canada.

The committee has been welcomed and encouraged by the Committee on Oceanography of the National Academy of Sciences and has been supported in its work by a grant from the National Science Foundation.

* * * *

The working force of scientists engaged in oceanography was estimated to be about 1200 in 1958 and, if it has continued to grow as in the recent past, is now probably about 1500. Of these nearly 60% hold advanced degrees, and one-third have taken the Ph.D. degree. The expanded program of research will require at least 120 technically trained recruits annually, of which 40 will have attained the doctorate if the educational qualifications of the working force is to be maintained. This is the task which the proposed program presents to our universities.

In our tradition the student is allowed to select his field of study according to the dictates of his personal curiosity, interest and imagination. On this basis the several disciplines compete to capture their disciples. In this competition oceanography is at a disadvantage, being the child of none of the recognized disciplines which sue for the students' favors. Yet here is a rich field for intellectual activity which as such is allowed to escape the attention of most students passing through our universities and colleges. There are, however, many subjects commonly presented which impinge so closely upon oceanography that the connections are obvious. These include ecology, meteorology, geology, hydraulics and, perhaps closest of all, limnology. The majority of the present oceanographers have entered the field through such disciplines or directly from the basic sciences.

The most immediate way to encourage the

[1] Previous discussion of the subject of this report may be found in "Education and Training for Oceanographers" by V. O. Knudsen, A. C. Redfield, Roger Revelle and R. O. Shrock, *Science* Vol. 111, pp. 700–703, 1950, and the report of the Committee on Oceanography of the National Academy of Sciences–National Research Council, "Oceanography 1960–1970," Chapter 8, Education and Manpower, and Chapter 12, Marine Sciences in the United States—1958. The committee acknowledges its indebtedness to these sources.

study of oceanography is to foster wider recognition of its relations to the disciplines already represented in the curricula of universities and colleges. The result should at the same time broaden and strengthen the position of these related subjects. It is to this end that the present report is prepared in the hope that it may assist the members of the American Society of Limnology and Oceanography to extend the presentation of oceanography as a pertinent subject for study in their own institutions and that it may aid students in electing their courses of study.

II. OPPORTUNITIES IN OCEANOGRAPHY

Throughout history the ocean has been a mystery and consequently a challenge. Since his early days on earth man has tried to comprehend and thus conquer this element. Curiosity about the unknown and the drive to understand is a human characteristic which impels the scientist in free research. The multitude of problems presented by the ocean have stimulated many students to devote themselves to their solution. The results have been of high importance to civilization, but still the ocean is incompletely understood and presents a great opportunity for discovery.

The origin of the ocean is intimately related to the history of the earth. Is the ocean a late phase in the development of the planet, or is it as old as the solid earth? The topography of the great ocean basins is more spectacular than that of the land and many submerged features have been preserved through geological ages. The most active regions of change in structure of the earth's crust lie along the margins of the oceans and along lines traversing the entire length of their basins. Thus the oceans are related to the origin of all chains of high mountains.

The thin sedimentary layers on the ocean floor facilitate the study of the geophysical processes and structure of the interior of the earth, such as the rate of heat flow from within, and the depth of the transition between crust and mantle. The low rate of sedimentation allows the superficial layer of sediment to be in contact with sea water for long periods and enables one to investigate the changes in the sediments caused by living organisms and by very slow chemical reactions.

Evidence of changing climate in the past is found in the upper layers of deep-sea sediments. Soon it may be possible to draw charts of the temperature distribution at certain depths as it existed millions of years ago. When such information is combined with evidence for the wandering of the poles, revealed by the magnetism of rocks and by the history of continental glaciation, we may come to understand the forces responsible for climatic change and even to forecast climate into the future.

The ocean is the birthplace of life. The record of ancient life preserved in sediments reveals the time of origin of different species and the evolution of organisms. Their distribution tells us the conditions for life in the water column above and by comparing these findings with present conditions we can reconstruct the distribution of temperature, salinity and current systems of the past.

The uptake of energy from the sun by living substances in the sea takes place near its surface where alone sufficient light penetrates to permit photosynthesis. Yet life exists down to the greatest depths. The flow of energy and of nutrient materials through the food chains of plants and animals and in the circulation of water is a central consideration, not only for understanding life in the abyss but for the assessment of the fertility of surface waters.

The greatest diversity of animal form exists among marine animals. This has pro-

vided the basis for much of the classification of animals and for many of our ideas about organic evolution. Genetic experiments and ecological observations are revolutionizing these concepts and offer new opportunities for the marine biologist. Similar diversity in the chemical composition and in the physiological mechanisms of marine organisms present an actively growing field for the biochemist and the physiologist.

Energy, water and other volatile materials are exchanged across the sea surface. The exchange of heat affects the circulation of water both as currents in the sea and as moisture in the atmosphere. Thus it influences the climate of the land. Droplets of salt water introduced into the air by breaking waves appear to provide nuclei about which raindrops form. The role of the sea in absorbing atmospheric pollutants arising from the burning of fuel and from atomic disintegrations is now receiving much attention. The wind systems of the earth are influenced by the distribution of land and water, and destructive hurricanes are born where critical conditions occur at the sea surface. Thus advances in oceanography are important to meteorology and climatology alike.

Central to all aspects of oceanography are the properties of sea water itself. The sea contains the largest homogeneous chemical mass on the earth's surface, in which almost all of the chemical elements are represented. These residues, originally dissolved from the rocks or emitted from volcanoes, provide essential data for geochemistry. The composition of sea water has established the environment in which organisms have evolved and now live, and appears to have determined even the chemistry of the body fluids of land animals. Difficult problems in analytical chemistry and subtle problems in physical chemistry arise from the small concentrations in which many elements are present and from the interactions which result from organic activity and from exchanges with the atmosphere.

The motions of ocean water are the result of the physical forces acting on it. Tides are produced by astronomical forces arising from the gravitational attraction by sun and moon; waves by the stress of the wind on the sea surface. The great current systems are related to the action of the earth's gravitation on the distribution of mass within the body of the ocean. Because of the size of the earth its rotation has a profound influence on the oceanic circulation. Theoretical hydrodynamics has been applied with noteworthy success to these phenomena but, as more has been learned about the sea's motions, new problems have arisen more rapidly than they could be solved.

Knowledge of the ocean has found application for the welfare of mankind as the need has arisen and the knowledge has become available. In the days of sail, the systematic description of the ocean wind- and current-systems showed the most effective courses for the ships of commerce. The submarine cable required the exploration of the ocean abyss. The analysis of the tides permits tidal forecasts second in precision only to the predictions of astronomy. Newly appreciated applications to military needs are responsible for much of the present support of oceanography but many civil problems also require scientific knowledge of the sea. These include the development and management of fisheries, the prevention of fouling and corrosion of ships and of materials exposed to sea water, the protection of beaches from erosion and of structures exposed to the attack of the sea, the winning of chemicals from sea water, the exploitation of the power of tides and waves, the disposal of wastes in coastal waters and at sea, and many others.

These examples should serve to illustrate what oceanographers do. The problems have a basic character which has attracted some of the best brains in science, and a scope to appeal to students of the most varied interests. The areas of the unknown are so great and new techniques for penetrating these areas are developing so rapidly that able students find the field attractive.

III. EMPLOYMENT

Prior to 1940 few individuals in the United States were actively working in the field of oceanography. Following the Second World War, a marked increase began which has continued steadily. A survey made in 1958 showed that there were about 1200 scientists permanently employed in oceanographic research and teaching, distributed among 60 institutions.[2] In addition to those employed permanently a large number of scientists visited oceanographic laboratories temporarily to conduct research on some aspect of marine science.

More detailed information on the present status of employment has been obtained from responses from 24 institutions to a questionnaire.[3] These institutions employ approximately 1300 scientists, or nearly nine tenths of the present working force. See

[2] Based on data secured by the Committee on Oceanography of the National Academy of Sciences and reported in part in "Oceanography 1960 to 1970, Chapter 12, Marine Sciences in the United States—1958."

[3] The statistics reported in this and the following sections of the present report are neither complete nor exact. This is because of the varied nature of the institutions engaged in oceanographic work, the lack of agreement on the definitions of the various categories involved and the different interpretations which may have been applied to the questions by those who answered the questionnaires. Because no single recognized pattern of education of oceanographers exists and many receive their advanced instruction in other disciplines it has been impossible to secure complete information on many aspects of education. Consequently data from selected groups of representative institutions have been used. Nevertheless, the committee believes that the numerical information presented supplies a useful indication of the manpower engaged in oceanography and of the numbers of students undergoing preparation for careers in the marine sciences.

TABLE 1. *Employment in oceanography in the United States in 1960 at 24 institutions*

Institution	Biological oceanography	Chemical oceanography	Geological[1] oceanography	Physical[2] oceanography	Total
Alaska Department of Fisheries	52	—	—	—	
Columbia University—Lamont Observatory	7	23	34	9	
Hudson Laboratories	—	—	5	79	
Duke University Marine Laboratory	7	—	—	—	
Florida State University	4	4	1	1	
Gulf Coast Research Laboratory, Mississippi	5	1	1	1	
Johns Hopkins University, Chesapeake Bay Institute	5	2	—	10	
New York University	—	—	—	31	
Oregon State College	2	—	1	4	
Stanford University, Hopkins Marine Station	4	—	—	—	
Texas A & M College	8	7	4	11	
University of California, Scripps Institution	40	8	24	34	
University of Delaware	10	—	1	—	
University of Hawaii	17	2	—	3	
University of Miami	38	18	6	17	
University of North Carolina	7	1	—	—	
University of Rhode Island	9	—	1	2	
University of Texas	9	1	3	—	
University of Washington	9	6	5	8	
U.S. Bureau of Commercial Fisheries	330	7	—	6	
U.S. Navy Hydrographic Office	12	—	29	185	
Virginia Fisheries Laboratory	16	—	—	—	
Woods Hole Oceanographic Institution	30	18	22	38	
Yale University	8	—	—	—	
Total	629	98	137	439	1303
Per cent	48	7	11	34	100

[1] Including geophysical oceanography.
[2] Including marine meteorology.

Table 1. The scientists contributing to oceanography fall into two groups which may be separated by the origin of their interest. The first group is concerned with describing and understanding the phenomena of the oceans as such. Its research is focused on the complex problems posed by the interaction of all the factors at play. The second consists of scientists whose primary interest is in some related field to which marine events are pertinent, such as meteorology, biology, geology and geophysics, or in some basic discipline which finds application to the problems of oceanography such as mathematics, physics and chemistry. It is difficult to separate investigators in terms of their motivation, but about two-thirds of those included in Table 1 appear to fall into the first category. Both groups are important to the over-all understanding of the ocean, and laboratories devoted to different purposes vary in the proportion in which the two groups are mingled.

Marine scientists may be classified according to the basic discipline in which they are most competent and which determines their specific approach to marine problems. Thus physical, chemical, biological and geological oceanographers may be recognized by their specialty. The survey indicates that among the 1300 scientists these specialties were represented in the following proportions:

Biological Oceanography	48%
Chemical Oceanography	7%
Geological Oceanography—including related geophysics	11%
Physical Oceanography—including meteorology	34%

The rapid growth of the working force in oceanography is shown in Figure 1. This figure is based on information secured from 22 of the institutions listed in Table 1, which employed about 750 scientists in 1960. Data from the U.S. Navy Hydrographic Office and the U.S. Bureau of Commercial Fisheries, which employ a large part of the biologists and physical oceanographers listed in Table 1, are excluded because no information for prior years is available. The total working force in these 22 institutions has increased steadily at an average rate of about 11% per year. If this rate is applied to the working force of 1200, as estimated for 1958 for 60 institutions, it follows that about 130 additional scientists were added to the force that year.

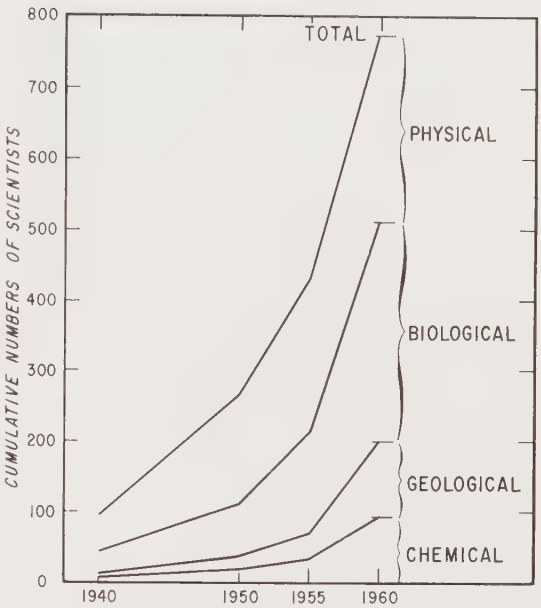

FIG. 1. Number of scientists employed in oceanography and its subdivisions at 22 institutions since 1940.

The growth of the special fields in oceanography is also shown in Figure 1. A comparison of the numbers engaged in each in 1950 and 1960 and the mean annual rate of increase during these ten years is as follows:

	Number employed		Mean annual rate of increase
	1950	1960	
Biology	70	287	15%
Chemistry	13	91	22%
Geology	19	108	19%
Physical Oceanography	157	248	5%
Total	259	734	11%

It may be seen that substantial increase in employment has occurred in all aspects of the subject, but it is noteworthy that physical oceanography has grown less rapidly than the field as a whole.

Of the 1300 men working at the institutions listed in Table 1 about 50% were employed by universities or by research

establishments closely associated with them and 30% were engaged in fisheries investigations under state or federal auspices. The remaining 20% were employed by the U.S. Navy Hydrographic Office. While the universities appear from these statistics to be the principal employers of oceanographers, it should be pointed out that a large part of their work is supported by the government which, by contract with these institutions, engages oceanographers to conduct surveys and to do research in the national interest.

In addition to the Hydrographic Office and the state and federal fisheries services, oceanographers are employed directly by governmental agencies such as the Coast & Geodetic Survey, Beach Erosion Board, Weather Bureau, Geological Survey and Atomic Energy Commission, and as science administrators in the various granting agencies. Specialists in marine science are engaged in assisting the development of underdeveloped countries under the auspices of the International Cooperation Administration, the Food and Agricultural Organization of the United Nations, UNESCO and other national and international agencies. In industry the petroleum companies have long had a number of oceanographers in their employ. Recently the employment by industry has been increasing, particularly in the aircraft, marine construction and instrument manufacturing companies. The shipbuilding and chemical industries also are adding qualified oceanographers to their research and production groups.

The future for employment in all aspects of oceanography is promising. The National Academy's Committee on Oceanography estimates that the research envisaged for the immediate future will require twice the present number of qualified marine scientists as a minimum. Because of the growing recognition of the subject, challenging positions in teaching and research are becoming available at universities, museums and secondary schools. A wide variety of endeavor awaits the well-trained oceanographer.

IV. PRODUCTION OF MARINE SCIENTISTS

The expanded program of research recommended by the Committee on Oceanography of the National Academy of Science will require the production of about 1200 additional oceanographers by 1968 to bring the total working force to some 2400 trained men. If the working force continues to grow at an average rate of 11% per year, as indicated by the data in Figure 1, it will number 2500 by 1965. Should it increase at the rate of 130 per year, as appeared to be the case in 1958, it will reach 2500 in 1968. Thus there is reason to believe that manpower will be available for the program only if the present rate of increase of recruitment is maintained or increased.

The rapid growth of oceanography has been in response to the increased recognition of its importance and the financial support which has resulted, particularly on the part of government. Recruits have been drawn from two sources: 1) men trained in the basic sciences and other subjects related to the marine sciences and 2) the graduates of university departments of oceanography.

The first source includes mathematicians, physicists, chemists, geologists, biologists and engineers who have found interest and congenial employment in oceanographic research. It has provided most of the staff of the Woods Hole Oceanographic Institution, and of such governmental agencies as the Coast and Geodetic Survey and Beach Erosion Board, and has supplied many employees to the fisheries services. The recent addition of oceanographers to the faculties at such institutions as Harvard, the Massachusetts Institute of Technology and the University of Chicago, which do not maintain departments of oceanography as such, promises that this source will continue to be fruitful in the future.

The second source has grown in importance as institutions such as Johns Hopkins University, the University of Miami, Texas A & M College, Florida State College and others have established oceanographic departments and as the earlier teaching insti-

TABLE 2. *Graduate students in residence in oceanography and marine sciences at 22 educational institutions during the years 1950, 1955 and 1960*

University or college	1950				1955				1960			
	Biol.	Chem.	Geol.[1]	Phys.[2]	Biol.	Chem.	Geol.[1]	Phys.[2]	Biol.	Chem.	Geol.[1]	Phys.[2]
Columbia University	5	—	—	—	—	2	4	—	5	—	10	5
Cornell University	—	—	—	—	—	—	—	—	5	—	—	—
Duke University	6	—	—	—	7	—	—	—	14	—	—	—
Florida State College	—	—	—	—	1	—	—	1	8	3	2	—
Harvard University	4	1	2	—	3	—	5	4	5	1	5	7
Johns Hopkins University	2	1	—	2	4	3	—	3	1	—	—	6
Massachusetts Institute of Technology	—	—	—	—	—	—	—	—	—	—	6	—
New York University	—	—	—	—	—	—	—	10	—	—	—	10
Oregon State College	—	—	—	—	—	—	—	—	2	—	—	8
Texas A & M College	1	1	—	2	15	7	6	20	8	7	8	2
University of California (Scripps Institution)	16	2	8	25	18	2	10	13	26	3	13	15
University of Georgia	—	—	—	—	2	—	—	—	3	—	—	—
University of Hawaii	9	—	—	—	8	—	—	—	25	2	—	—
University of Miami	22	1	—	—	28	—	—	1	58	2	1	5
University of Michigan	—	—	—	—	—	—	—	—	1	—	1	—
University of Rhode Island	8	—	—	—	2	—	—	—	11	—	—	—
University of Southern California	5	—	6	—	5	—	8	—	4	1	10	—
University of Texas	2	—	—	—	2	—	—	—	8	—	3	—
University of Washington[3]	—	1	—	—	4	3	2	6	8	3	8	17
University of Wisconsin	3	1	3	2	3	—	6	2	4	—	6	4
William and Mary College	2	—	—	—	3	—	—	—	6	—	—	—
Yale University	2	—	—	—	4	—	—	—	7	—	—	—
Total	87	8	19	31	109	17	41	60	209	22	73	79
Total, all fields	145				227				383			

[1] Combined geological and geophysical oceanography.
[2] Includes meteorological oceanography.
[3] Excludes students from separate college of fisheries, and departments of geology, meteorology and Zoology of which some are working on marine problems.

tutions at the Universities of California and Washington have expanded. These institutions probably educate more than half the recruits to the subject at present and the proportion is likely to increase since they provide a definite place where undergraduates wishing to become oceanographers can find well balanced training, and from which they can be drawn by employers seeking qualified personnel.

The enrollment of graduate students in the universities offering training in oceanography has increased steadily. The information in Table 2, based on data supplied by 22 of the principal training schools indicate that their numbers have increased by a factor of 2.64 since 1950. This represents an average rate of growth of 10% per year, which is nearly that of the working force as a whole.

The number of advanced degrees awarded to graduate students in 17 of these schools during the past decade is given in Table 3. There appears to have been very little increase in the number of Master's degrees awarded. The number of Ph.D. degrees, however, has increased at an average rate of about 10% per year, thus keeping pace with the growth of enrollment and of the working force. It is anticipated that 34 Master's and 20 Doctor's degrees will be granted in 1960.

Of the 1200 men known to be engaged in 1958 in oceanographic research and teaching nearly 400 held the Doctor's degree and 300 the Master's degree. To double this working force in ten years without loss in

TABLE 3. *Advanced degrees in oceanography and marine sciences given at 17 educational institutions during the periods 1950–1954, 1955–1959 and estimate for the year 1960*

University or college		1950–1954				1955–1959				Estimate for 1960			
		Biol.	Chem.	Geol.[1]	Phys.[2]	Biol.	Chem.	Geol.[1]	Phys.[2]	Biol.	Chem.	Geol.[1]	Phys.[2]
Cornell University	M.S.	—	—	—	—	1	—	—	—	—	—	—	—
	Ph.D.	2	—	—	—	—	—	—	—	—	—	—	—
Duke University	M.S.	8	—	—	—	4	—	—	—	2	—	—	—
	Ph.D.	3	—	—	—	5	—	—	—	1	—	—	—
Harvard University	M.S.	—	—	—	—	—	—	—	—	—	—	—	—
	Ph.D.	5	1	5	1	5	—	5	1	1	—	1	—
Johns Hopkins University	M.S.	—	1	—	6	2	2	—	2	—	—	—	1
	Ph.D.	—	—	—	—	—	1	—	1	—	—	—	1
Massachusetts Institute of Technology	M.S.	—	—	—	—	—	—	—	—	—	—	1	—
	Ph.D.	—	—	—	—	—	—	—	—	—	—	—	1
New York University	M.S.	—	—	—	—	—	—	—	8	—	—	—	—
	Ph.D.	—	—	—	—	—	—	—	3	—	—	—	—
Texas A & M College	M.S.	2	2	1	4	4	4	5	8	2	1	—	—
	Ph.D.	—	—	2	—	2	3	2	8	2	2	1	1
University of California (Scripps Institution)	M.S.	9	5	11	20	5	3	6	7	3	—	1	—
	Ph.D.	1	—	7	12	9	2	8	8	—	1	2	1
University of Georgia	M.S.	—	—	—	—	—	—	—	—	1	—	—	—
	Ph.D.	—	—	—	—	2	—	—	—	—	—	—	—
University of Hawaii	M.S.	10	2	—	—	2	1	—	—	1	—	—	—
	Ph.D.	3	—	—	—	4	—	—	—	—	—	—	—
University of Miami	M.S.	20	1	—	—	23	—	1	—	13	—	—	—
	Ph.D.	—	—	—	—	—	—	—	—	—	—	—	—
University of Rhode Island	M.S.	6	—	—	—	7	—	—	—	1	—	—	—
	Ph.D.	—	—	—	—	—	—	—	—	—	—	—	—
University of Southern California	M.S.	1	—	8	—	4	—	13	—	—	—	—	—
	Ph.D.	3	—	2	—	1	—	4	—	—	—	1	—
University of Washington[3]	M.S.	—	—	—	1	1	3	1	6	—	—	—	2
	Ph.D.	—	—	—	—	1	1	—	1	—	—	—	—
University of Wisconsin	M.S.	3	—	—	2	2	—	1	1	1	—	1	—
	Ph.D.	2	—	3	1	2	—	4	—	1	—	2	—
William and Mary College	M.S.	4	—	—	—	6	—	—	—	2	—	—	—
	Ph.D.	—	—	—	—	—	—	—	—	—	—	—	—
Yale University	M.S.	1	—	—	—	3	—	—	—	1	—	—	—
	Ph.D.	1	—	—	—	4	—	—	—	1	—	—	—
Total	M.S.	64	11	20	33	64	13	27	32	27	1	3	3
Total	Ph.D.	20	1	19	14	35	7	23	22	6	3	7	4
Total M.S., all fields		128 (25 per year)				136 (27 per year)				34			
Total Ph.D., all fields		54 (11 per year)				87 (17 per year)				20			

[1] Combined geological and geophysical oceanography.
[2] Includes meteorological oceanography.
[3] Excludes degrees from separate college of fisheries and departments of geology, meteorology and Zoology of which some candidates are working on marine problems.

quality Doctors must be produced at an average rate of 40 per year. Since the Master's degree is usually taken by those who continue to the doctorate about 40 Master's degrees are required to maintain the output of doctorates in addition to 30 who enter the working force without additional education. Thus the required annual quota of Master's is about 70. It is evident that the institutions listed in Table 3 which are the principal

source of trained oceanographers, are producing graduates at a rate that is less than half the requirement.

The training in the several sciences required for the investigation of oceanography is specialized. It is pertinent to inquire to what extent students are being prepared for the different kinds of research needed. While the proportions of the different specialties in the present working force are not necessarily those which will be wanted in the future they provide a basis for comparison with the present enrollment for specialized instruction. The data in Table 2 indicate that the present enrollment of graduate students in the specialties is related to the numbers in each specialty of the total working force as follows:

	Working force	Students in training
Biological Oceanography	48%	55%
Chemical Oceanography	7%	6%
Geological Oceanography	11%	19%
Physical Oceanography	34%	21%

The proportion of students now specializing in biology appears to be sufficient to maintain the present representation in the working force. The proportion of chemists in training is about the same as in the working force. Chemistry is, however, the most poorly represented specialty. We believe the proportion of students in this discipline should be greatly increased. The proportion of geologists in training is greater than in the working force. Enrollment in geology has increased rapidly over the past decade and this specialty appears to be developing adequately. The situation in physical oceanography is unsatisfactory. While 34% of the working force is employed in this specialty it accounts for only 21% of the student enrollment. The need for strengthening this field is confirmed by the fact that there is at present a greater demand for physical oceanographers for employment than for men trained in any of the other specialties.

In order to determine the relation between the number of students recruited annually, the number of candidates for advanced degrees enrolled at any one time and the number of degrees awarded, the data in Table 4 has been secured from four univer-

TABLE 4. *Annual recruitment and enrollment of graduate students and advanced degrees granted in four departments of oceanography*

Year	New recruits	Enrollment of candidates		Degrees granted	
		M.S.	Ph.D.	M.S.	Ph.D.
1950–1951	38	46	15	11	6
1951–1952	30	50	36	10	4
1952–1953	31	55	33	16	8
1953–1954	29	47	55	7	2
1954–1955	32	50	50	6	6
1955–1956	27	60	37	10	7
1956–1957	24	50	58	16	10
1957–1958	27	61	57	8	12
1958–1959	40	72	56	14	10
1959–1960	46	81	49	10	10
Totals	324	572	446	108	75
Proportion	100	177	138	33	23
Numbers to produce 40 Ph.D.'s per year	173	305	238	62	40
Total enrollment to produce 40 Ph.D.'s per year		543			

Data from Scripps Institution, Johns Hopkins University (1958–1960 only), University of Washington and Texas A & M College.

sity departments of oceanography. During the ten-year period, 1950–1960, these institutions admitted 324 students for graduate education in oceanography. Of these, 108 were granted Master's degrees and 75 received Doctor's degrees. The sums of the annual enrollment of candidates for the Master's degree was 572 and that for the Doctor's degree was 446.

From the proportions of these numbers it appears that on the average in any one year for every 100 new students recruited a standing crop of 177 graduate students were enrolled as candidates for the Master's degree, of which only 33 eventually received that degree. Thus two-thirds of the recruits failed to enter the profession with an advanced degree. While the proportion of recruits who failed to obtain the Master's degree appears to be unduly high it is probably not out of line with general graduate school experience when it is considered that the recruitment included a substantial number of foreign students and of military personnel who were not allowed sufficient time in residence to

qualify for the degree. Of those who received the Master's degree two-thirds continued their studies and took the Doctor's degree, leaving one-third to enter the working force.

If these statistics can be taken as representative of the training of marine scientists in general, it appears that to produce an annual quota of 40 Ph.D.'s per year, as required for the proposed expansion of oceanographic research, about 173 new recruits should enroll for graduate training each year and some 543 graduate students should be in training at any one time. It is known that 383 graduate students are enrolled at the present time in 22 of the principal institutions which are educating marine scientists. This is only 70% of the estimated requirement. While the numbers of trained oceanographers entering the working force will be supplemented by others it is apparent that a substantial increase should be made in the enrollment of graduate students in oceanography.

Estimates received from the institutions listed in Table 2, which report a total enrollment of 383 graduate students in 1960, indicate that they have a maximum capacity of 662 students. This would permit nearly doubling the student body. However, a number of departments are occupied to capacity and some are overcrowded. Several departments report that further expansion of their teaching programs is limited by the teaching force available. It is evident that additions are needed both to the physical facilities and the teaching personnel in the marine sciences.

In physical oceanography, particularly, the situation is unsatisfactory. If this specialty is to maintain its present strength as the working force is increased about 14 men should be graduated with the Doctor's degree each year. This would require an annual enrollment of 190 graduate students specializing in physical oceanography. The maximum capacity estimated is 122, which is far short of the requirement.

It is not possible to draw a clear distinction between facilities for education and facilities for research in the case of a university graduate school. The completion of creditable and original research is a general requirement for the Ph.D. degree which makes a demand on the institution's resources for investigation. The university departments are responsible for a large part of the research effort in oceanography both through the work of graduate students and through investigations directed by their staff. The expanded program of research envisaged for the next decade will undoubtedly make a more serious demand on the research facilities of these departments than the foregoing statistics indicate.

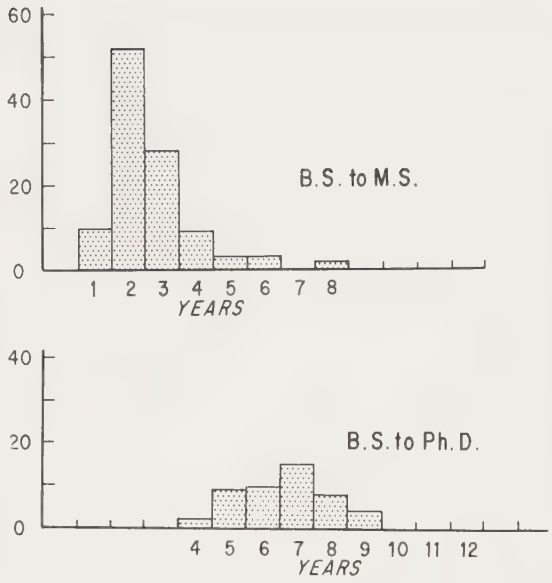

FIG. 2. Time elapsing between taking Bachelor's degree and higher degree by students in graduate schools of oceanography. Not corrected for interruption of residence or part-time employment. Ordinate, number of men in each year class.

The rate of production of trained oceanographers and the facilities required for their instruction depend not only on the numbers of students enrolled, but also on the time required for their education. The history of recent graduates from five of the larger departments of oceanography has been examined to determine the time which elapsed between graduation from college and the receipt of an advanced degree. Figure 2 shows the frequency distribution of the total periods in the case of 107 students

who received the Master's degree and of 51 who took the Doctor's degree. The greatest number of candidates for the Master's degree required two years to complete their course. The distribution is heavily skewed, however, and more than half the students required longer periods. Very few took the Master's degree in the minimum period of one year. In the case of the Doctor's degree seven years of graduate study appears to be the mode.

Ideally a qualified student of oceanography should not require more than two years to complete his work for the Master's degree and three additional years for the Doctor's degree. These times are longer than is frequently needed in the sciences in first class universities because they allow for the fact that students acquire little acquaintance with the subject while undergraduates and that some practical experience at sea is desirable. The information contained in Figure 2 shows that this ideal is attainable but that in the majority of cases it is not realized.

The prolonged period of graduate study which many students undergo is due to the fact that they are being supported by part-time employment. In the case of some students who have necessary jobs this is unavoidable. The majority, however, are employed as assistants on research contracts held by their universities. A limited amount of such employment is valuable in providing practical training. An excess is disadvantageous because it retards the rate at which trained men enter the working force and because it is an inefficient use of educational facilities and may not provide the best quality of education. An indispensable part of the training for an advanced degree is experience in finding and delimiting a significant problem for research and working out a plan for its solution. This experience may not be provided by assisting in the solution of a predetermined problem.

At present few students can afford graduate study without financial assistance. The undergraduate scholarships and graduate fellowships supported by endowment funds in colleges and universities are open to students of aquatic science in competition with those from other branches of learning. The same is true of pre- and post-doctoral fellowship programs supported by the National Science Foundation and the Department of Health, Education and Welfare and by private foundations such as those which administer the Guggenheim, Woodrow Wilson and Lalor Fellowships, among others. Fellowships earmarked specifically for oceanography are offered to graduate students by the Woods Hole Oceanographic Institution for summer and year round study, and pre- and post-doctoral training is supported at the Scripps Institution of Oceanography by grants from the Ford Foundation. A limited number of graduate students acquire support and useful experience as laboratory assistants and instructors.

These sources of support are entirely inadequate to provide for the students now in training, let alone the increased numbers that are needed. As a result the majority of graduate students are dependent on part-time employment as assistants in research projects. In many cases the fellowship stipends are also too small to attract students in competition with the better-paid jobs as research assistants. The production of trained oceanographers would be accelerated if more adequate fellowships and scholarships, earmarked specifically for the purpose, were available.

* * * *

If the present rate of increase in employment is maintained in the future, the numbers of recruits to the working force will be sufficient to provide for the proposed expansion of oceanography. In the past the number of Doctor's degrees granted in the marine sciences has increased nearly in proportion to the growth of the working force. However the actual number of men being trained specifically for oceanographic research would have been insufficient to maintain the quality of the working force as it has grown, had it not been supplemented by recruits from other disciplines. At present the enrollment of graduate students of oceanography is inadequate to produce the

required number of men prepared for leadership in the proposed program. It is necessary to increase the enrollment in the graduate schools of oceanography and to continue as well the recruitment of men trained in the basic sciences and other disciplines related to oceanography.

The existing graduate schools of oceanography should be adequate to care for the required increase in enrollment if strengthened by additions to their physical facilities and teaching force. At present the provisions for training physical oceanographers in particular are inadequate.

The period of graduate study required to obtain an advanced degree in the graduate schools of oceanography is longer than in many scientific disciplines and in some cases is unduly long. This situation could be improved if more adequate scholarships and fellowships were available to students in the marine sciences.

V. EDUCATION

Oceanography is concerned with all aspects of the oceans, their contents and boundaries. Its subject matter thus includes aspects of related divisions of geophysical and biological science such as meteorology, geology, taxonomy and ecology. As in all these subjects the basic tools of investigation are the principles and techniques of the more exact scientific disciplines, mathematics, physics and chemistry. To understand the oceans, however, it is necessary to take into account the interrelations of the physical, chemical, geological and biological processes operating within the mass of water at its boundaries. This is the essence of the subject. Thus the oceanographer requires a broader acquaintance with all the sciences than the student in the basic disciplines commonly attains.

Since the study of the ocean must be conducted in large part from ships at sea, the student should acquire familiarity with the techniques adapted to the great extent and depth of the oceans, and with the arts of navigation and seamanship. He should learn how to plan observational programs which will test hypotheses about the sea, how to operate and devise instruments which will secure required information, and how to analyze the data so obtained. Oceanographic research frequently requires the cooperation of individuals competent in different specialties. The prospective oceanographer needs a broad enough perspective to work effectively with other specialists and to understand the discipline which good teamwork requires. He should be familiar with the practical elements of personal and group morale and of safety aboard ship, and with the importance of rigorous planning and administration.

Thus the distinctive requirements of education for a career in marine science are an unusually broad knowledge of the basic sciences in addition to the special knowledge and skill unique to ocean studies.

Practical training must be acquired by on-the-job experience and can be obtained only at suitably equipped stations at the seacoast or on the Great Lakes. All other requirements may be met by, and are appropriate to, any university. Basic courses appropriate to preparation for graduate study are available at many undergraduate colleges.

General recognition of the importance of oceanography is so recent, and its content is so diverse, that no accepted pattern exists for education in the subject. The older men contributing to the marine sciences attained their degrees in one of the classical divisions of science, without specific training in oceanography and were later attracted to the field by the opportunities it offered to their talents. This pattern continues as developing research institutions create demands for mathematicians, physicists, chemists, geologists, biologists and engineers. Others receive their graduate training in university departments such as those teaching geophysics, meteorology, limnology, ecology or fishery biology in which aspects of oceanography are recognized as a pertinent part of the special field. The establishment of research institutes at several universities, as

at Yale, provides for more explicit training in the subject as such, but in these universities the student receives his degree through, and meets the general requirements of, one of the classical departments. Recently several universities have created independent departments of oceanography with all usual powers for promoting education in the field.

At present there is no agreement as to which of these several patterns is best. Some believe that the independent department is necessary to assure the breadth of training required. Others favor training in a special discipline in the first instance as being more likely to lead to higher competence. Opinions differ pretty much in accordance with the particular route by which each oceanographer has entered the field. It is healthy that varied programs are open to the prospective student.

Some 20 universities in the United States provide graduate education leading to the Ph.D. degree in Oceanography or in a related field which recognizes some aspect of the subject as pertinent. The institutions giving advanced training are relatively new and are developing rapidly and with vigor. With the growth and strengthening which may be expected normally, and assuming that people educated in the basic disciplines will continue to be attracted to marine science, these universities should be adequate to care for the specialized advanced training of the additional oceanographers which will be required in the future.

The committee does not feel that the establishment of new centers for graduate training is urgent, though it may be desirable in certain areas such as Alaska where the educational opportunities may be appropriately expanded. The teaching programs of existing departments and institutes should be expanded and should receive the support requisite for such expansion.

The most serious problem raised by the growth of oceanography is the recruiting of students of high caliber. Because the subject is not generally recognized as a part of any one of the classical disciplines this rich field for intellectual activity is allowed to escape the attention of most students who pass through our universities and colleges. In a number of institutions certain departments have recognized that aspects of oceanography are related by content and intellectual approach to their general field and have added oceanographers to their staffs. These departments teach such subjects as geology, meteorology, hydrodynamics, fishery biology, ecology and limnology. In this way oceanography has been brought to the attention of able students by arrangements which at the same time strengthen the offering of the department. Many oceanographers have entered the field through such associations and it is through them that the subject may be most readily introduced into the undergraduate curriculum.

Opportunity to contribute to education in the marine sciences is not limited to institutions located on the seacoast. The problems encountered in the ocean differ from those of lakes primarily in scale rather than principle. Freshwater institutions may broaden their offerings in aquatic science by including oceanography in their educational programs.

The University of Washington appears to be the only institution presenting oceanography as a field of concentration for undergraduates leading to the Bachelor's degree. There the Department of Oceanography offers two programs: 1) an elective curriculum which provides a basic introduction but allows wide choice of electives in other fields, and 2) a prescribed curriculum which requires more specialized study. A number of institutions including Cornell University and the Universities of Michigan and Wisconsin, provide counsel in oceanography to undergraduates and present undergraduate courses through members of the faculty connected with one of the recognized departments. At Harvard an interdepartmental committee on oceanography is available to provide guidance to students. Where graduate departments or research institutes of oceanography exist, as at the University of Miami, Texas A & M College and Yale University, guidance to undergraduates is available from the personnel of such establishments.

The committee recommends that undergraduate students be given better opportunity to become acquainted with the subject matter of oceanography through the presentation of elective courses and the provision of counsel in the field. It points out that this may be most readily accomplished through departments which recognize the pertinence of its content to their particular field.

Educational programs

The following discussion is offered for the guidance of those concerned with the develoopent of education in oceanography and of students who may consider entering the field.

It is not possible, nor indeed would it be desirable, to outline a program of education for the prospective oceanographer except in the most general terms. At each institution the program of instruction must be limited by the course offerings available and the interests of the faculty. The diversity of the problems in oceanography provide an appeal to practically every kind of scientific interest. The beginning student is rarely in a position to evaluate the direction in which his abilities may be effectively applied until he has learned more about himself and the opportunities which the subject has to offer. Tight categorical schedules stifle both interest and natural bent and are apt to educate toward a preconceived idea of the student's future career. One recommendation may be made, however, without reservation. Within the limits set by a major field of undergraduate concentration *the prospective oceanographer should obtain the broadest possible understanding of the basic sciences.*

Study of the basic sciences should be the prime objective of the undergraduate years. It should begin as soon as possible so that the student may arrive early at that stage of preparation where the several disciplines interdigitate and provide the unified background for the interpretation of the natural phenomena of the sea.

The undergraduate will naturally elect some one of the sciences as a major. This subject should be carried as far as possible in college and continued into the graduate years until general professional competence is reached and he is ready to undertake research work on some chosen aspect of oceanography. At this point planning and guidance of his training may be presumed to be in the hands of an experienced oceanographer.

Except for the specific body of knowledge unique to the oceans, the components of education in the basic sciences are available in practically every university. In preparation for eventual graduate work in oceanography the student should study:

1. Mathematics through differential and integral calculus.
2. Basic physics, including mechanics, heat, sound, light, electricity and magnetism.
3. Chemistry through quantitative analysis.
4. A year of biology, botany, or zoology.
5. A year of geology.
6. Two modern foreign languages.

In addition the student should obtain field experience appropriate to his undergraduate major.

The science courses should be at the level required for a major in the subject.

Since the graduate student will need to read the technical literature of his subject with ease and will be required to demonstrate his ability to do so before becoming a candidate for the Doctor's degree it is very desirable that the language study be completed prior to graduate work. German, Russian and French appear to be the languages most useful to the aquatic scientist at present. Because of the increasing international contacts among oceanographers and their employment in foreign service the ability to speak one or more foreign languages has become a great asset.

A major field of undergraduate study should be selected according to the student's intended specialization in marine science. Special subjects recommended for study, either as part of the undergraduate or graduate program are:

For physical or meteorological oceanography

Advanced mechanics or theoretical physics
Advanced or applied mathematics including vector analysis
Hydrodynamics or fluid mechanics
Thermodynamics
Wave theory and acoustics
Differential equations
Theoretical meteorology
Physical chemistry
Electronics, with laboratory

For chemical oceanography

Physical chemistry
Biochemistry
Organic chemistry
Microchemical analysis
Differential equations
Thermodynamics
Nuclear physics
Physiology
Ecology

For biological oceanography

Invertebrate and vertebrate zoology
Microbiology
Animal or plant physiology
Ecology
Genetics
Organic chemistry
Biochemistry
Biophysics, including applications of nuclear physics
Statistics

For geological oceanography

Structural geology
Mineralogy and petrology
Sedimentology or marine geology
Geophysics
Paleontology
Physical chemistry
Nuclear physics and chemistry
Ecology

While the basis of education for oceanography exists in many colleges and universities, students will not be attracted to the subject unless its nature is presented to them explicitly, some formal recognition is given to its value, and leadership is provided by the faculty. A course on the principles of oceanography is needed to acquaint the student with its subject matter and to give concrete meaning and purpose to the more general subjects included in his curriculum. Such a course would not only orient the prospective oceanographer but would have general educational value in demonstrating the application of the basic sciences to the complex situations encountered in nature. It would be useful in broadening the outlook of students in the physical sciences, geology and biology. Such a course should be available at the junior or senior level, after the student has had some introduction to the sciences. Institutions undertaking graduate instruction will naturally provide advanced courses in special aspects of oceanography in accordance with the interests of their faculties.

Undergraduate students cannot be expected to elect a program in preparation for a career in oceanography unless a qualified member of the faculty is responsible for its development. His duties would be to provide for the course of instruction and to give counsel to students interested in the subject. He could perform a valuable service in acquainting his colleagues and the administration with the relation of oceanography to other fields of learning. In some institutions, particularly those in which geophysics, meteorology or limnology are presented, qualified persons may be present on the faculty. In most cases, however, the appointment of an oceanographer will be required.

Practical field experience

Undergraduates preparing for careers in oceanography should obtain some first-hand contact with the ocean, and graduate students beginning research require facilities for obtaining data at sea. Provision for such experience cannot ordinarily be provided directly by universities except those which maintain marine research facilities.

The importance of field experience has been recognized for many years by biologists, and seaside laboratories under university operation exist in practically every

seaboard state. Summer courses in marine biology given at such laboratories have made an invaluable contribution to education, not only by presenting subject matter in the field but also by enabling the student to profit from experiences and contacts which his home institution does not provide. The limitation of many seaside biological laboratories is that they do not maintain vessels large enough to venture far to sea and thus study is confined to shallow coastal waters.

Courses in oceanography are available in summer at a number of seaside laboratories as at the Friday Harbor Laboratories of the University of Washington, the University of Florida, the University of Miami, and from time to time at the Duke Marine Laboratory at Beaufort, North Carolina. Oceanography could profit by the example set by the Marine Biological Laboratory at Woods Hole, which presents courses in biology as the joint effort of teachers drawn from several universities. This arrangement enables teachers of great talent to be assembled and is particularly suitable in a subject of such varied content as oceanography. Such a course, if given at an institution with access to deep water and if provided with a vessel suitably equipped to take students to sea, would be a valuable instrument for education in the marine sciences.

Facilities for research at sea and training in the practical techniques of oceanography are available to graduate students only at the universities and research institutions which maintain sea-going vessels. Graduate study can be undertaken profitably only at such universities or those through which experience at sea can be arranged at a seaside facility. In this connection the Woods Hole Oceanographic Institution has established scholarships to encourage the participation of graduate students from the universities in its work and has entered into part-time arrangements so that members of its staff have appointments with institutions which do not maintain sea-going facilities, such as Harvard, the Massachusetts Institute of Technology and the University of Chicago. Such cooperative arrangements should be encouraged and expanded to provide similar opportunities at other oceanographic laboratories.

Special opportunity for the expansion of education for oceanography exists in the universities of the Great Lakes area. A number of these have been active for many years in the fields of aquatic biology and limnology and are already teaching and conducting research in many aspects of oceanography. Ohio State University has supported a productive research laboratory on Lake Erie and at the University of Michigan the Great Lakes Research Institute provides a center from which a broad program of investigation of the larger lakes is being conducted. Many of the concepts and techniques employed in the study of the Great Lakes are identical with those of oceanography. Small lakes, in which conditions may be controlled and experimentally modified, are advantageous for giving students experience in the study of many special problems in aquatic science. Many men trained in the Great Lakes area are contributing effectively to oceanography.

Adequate ships are badly needed for research which should be done in the Great Lakes. Until they are available the opportunities for providing students with practical experience in the techniques of oceanographic investigation in this area will be limited.

* * * *

Existing universities and research institutions are in a position to provide education and training to considerably increased numbers of oceanographers, provided their capacity is fully realized. To this end some expansion of the present teaching staff and increased facilities are required. The rounding out of the teaching staff by such expansion should improve the quality of the education available.

In order to bring the subject to the attention of students and to facilitate increased cooperation between existing departments within each university, and between the universities and research institutions which have assumed a responsibility toward education, relatively minor reorganization of academic machinery is required.

VI. CONCLUSIONS AND RECOMMENDATIONS

The development of the marine sciences anticipated in the immediate future will require at least doubling the number of scientists employed in oceanography and related fields. Perhaps no other area of science offers a greater range of opportunity to students of varied interest. At the present time the greatest shortage of personnel is in physical oceanography and inadequate numbers are undergoing training in this specialty. The number of chemical oceanographers, both employed and in training, is increasing rapidly. This aspect of marine science has been neglected, relative to the subject as a whole, and can anticipate rapid expansion. The same is true to a lesser extent of marine geology. In biology the numerical situation is more satisfactory. The greatest need is for men broadly trained in the sciences requisite for the interpretation of the relation of the organisms to the environment.

The existing resources of universities and colleges are adequate to provide the basic education for students of oceanography, but better provision is needed for the guidance of students, for the presentation of the subject itself, and to make practical experience in research at sea available to them. The special education of increased numbers of graduate students can be provided by existing university departments if support for a proportionate increase in teaching staff and facilities is forthcoming. The most pressing need, however, is for vigorous effort on the part of oceanographers, aquatic scientists and others with related interests to bring these opportunities to the attention of prospective students.

Leadership in attracting students to oceanography and in providing for improvements in their education must come primarily from the teachers and investigators now concerned with the subject. By individual personal effort, as well as concerted action, they alone can effectively bring the challenging problems and inviting opportunities for careers in oceanography to the attention of students at all levels, and they are the ones in the most effective position to initiate improvements in the provisions for education in their respective institutions.

Educational facilities

To provide for the required expansion of facilities for the education of oceanographers this committee recommends:

(1) That universities and colleges both coastal and inland with facilities in the basic sciences adequate to provide undergraduate education preparatory to advanced study in oceanography, be encouraged to establish curricula for this purpose. Where this is done guidance for students should be provided, either by a qualified member of the faculty or through the part-time services of an oceanographer from another institution, and introductory courses in oceanography should be made available to undergraduates.

(2) That graduate and postgraduate education in oceanography, including the necessary opportunities for training in research at sea, should be expanded. This may be done most readily by additional support for existing departments of oceanography and by broadening the offerings of departments, such as geology, geophysics, meteorology, limnology and biology, to which oceanographic phenomena are pertinent.

(3) That governmental and private institutions for marine research, which do not provide formal education in oceanography, be encouraged to contribute to the training of oceanographers by arranging to provide personnel to teach at educational institutions, to supervise the research of their graduate students, and by making facilities for research at sea available to their students and faculties.

The establishment of departments of oceanography at additional universities is not urgently required at present. The facilities for the training of students for research at sea, and indeed for aquatic research in general are inadequate, especially on the Great Lakes and in Alaska.

The implementation of the foregoing recommendations will require financial support from state and federal sources, and from private foundations. Funds will be required to:

(1) Provide positions for teachers on a reasonably long-term basis, say for a minimum of five years. Oceanographers will not be inclined to enter careers as teachers on a more temporary basis.

(2) Provide physical facilities such as classrooms, laboratories for instruction and graduate research, and equipment for both teaching and research.

(3) Make vessels available for the instruction of students in the practical techniques of research at sea.

Support for students

If increasing numbers of students are attracted to oceanography greater financial support in the form of scholarships and fellowships will be required to supplement the rather inadequate funds which are available at present. The committee recommends that additional support for students be made available by the provision of:

(1) Scholarships and fellowships specifically for study in the marine sciences. It is recognized that oceanography hitherto has been neglected in comparison to long-established sciences, that there has been less support available for its students, and that the rate of growth of oceanography should be increased in comparison to that of science in general.

(2) Increased scholarship support for promising undergraduates pursuing studies preparatory to advanced work in oceanography. There is now a conspicuous lack of funds for this purpose. Such grants should include funds for summer study at marine laboratories and for participation in training cruises on research ships, including the travel expenses involved.

(3) Fellowships in oceanography granted for longer tenure and with adequate stipends, recognizing that the education of graduate students in oceanography is more time-consuming and arduous than in most branches of science.

(4) Increased numbers of post-doctoral fellowships. The group of students who are attracted to oceanography after completing graduate training in the basic or other sciences in particular are in need of support during this stage of their career.

(5) Increased numbers of graduate and post-doctoral fellowships for study at foreign centers of research. These should provide for the necessary expenses of travel.

Fellowships and scholarships should be awarded on individual merit and irrespective of the particular oceanographic specialty. They should be available also in peripheral fields, such as international marine law or marine economics. Some scholarships and fellowships should be awarded to the student in a manner that allows free choice of the educational institution to be attended. Others should be supported by grants to institutions which would select the students and administer the funds.

The federal agencies which at present support students in oceanography are, primarily, the National Science Foundation and the Department of Health, Education and Welfare. Other governmental agencies, having large responsibilities in aquatic science, such as the Atomic Energy Commission, the Bureau of Commercial Fisheries, the Coast and Geodetic Survey and the Navy Department, should also provide fellowship support, both as a means of adding to the supply of trained oceanographers and as a means of bringing to the attention of bright students the problems falling within the provinces of such agencies. Such fellowships might well be offered for study and research within the general scope of interest of the agency concerned.

Supplemental activities

To attract able students to oceanography and to supplement their formal training the

following activities should be encouraged and supported:

(1) Open house programs and lectures, to be arranged at centers of activity in aquatic science to awaken interest among local students.

(2) The preparation of textbooks and monographs which are greatly needed in many branches of the marine sciences for educational purposes and which would tend to attract interest in the ocean.

(3) The participation of oceanographers in summer institutes for training science teachers and support for summer courses for high school students.

(4) Visiting lectureships, to present the marine sciences in schools, colleges and universities throughout the nation. The American Society of Limnology and Oceanography should sponsor such lectureships and seek support from appropriate foundations.

(5) Symposia for the discussion of particular subjects in the marine sciences, in which participation by advanced students should be encouraged.

(6) International meetings such as the Oceanographic Congress held in New York in 1959 and the International Congress of Limnology to be held in Madison, Wisconsin under the sponsorship of the American Society of Limnology and Oceanography in 1962.

The committee believes that concern over the recruitment of qualified investigators to conduct the expanded program of research in oceanography may be dispelled if action such as it has proposed is taken. Funds for education will only be forthcoming if there is promise of positive action on the part of the institutions concerned with training marine scientists, in the form of specific requests for support of concrete educational programs which the institutions are ready to initiate. The committee is prepared to aid and advise individuals or institutions who are interested in developing programs of education in the marine sciences.

Information for Contributors

Editorial Policy: Original papers based on research in any aspect of limnology and oceanography will be considered for publication in this journal. The papers will be judged on the basis of their contribution of original data and ideas or interpretation. Review articles will not be accepted unless specifically solicited, or unless the review leads to new and important generalizations.

All manuscripts are to be in English, although the abstract may be presented in another "congress" language in addition to English. Papers will be limited to 24 printed pages, including tables and figures, which should not exceed 20 per cent of the total length of the paper. The cost of any excess may be charged to the author. Ten manuscript pages reduce approximately to four printed pages. Folded inserts, envelope inserts, and colored illustrations cannot be printed unless paid for by the author.

Manuscripts are to be typed, double-spaced throughout, on good quality paper 8½ × 11 inches. The sequence of material in the manuscript as submitted should be: title page, abstract, the manuscript proper, references, tables, figure legends, and figures.

1. The *title page* should include the title, author's name, and address. A condensed *running head* of no more than 60 letters and spaces should be provided.

2. The *abstract*, limited in length to 3 per cent of the article, should be informative, concise, and complete in itself without reference to the body of the paper. Two copies should be submitted, one of which will be sent to Biological Abstracts or to any other abstracting journal designated by the author.

3. The *manuscript*. Acknowledgments should be made preferably in the introduction or else as a footnote to the title. Make certain that each figure and table is referred to in the text. Literature references in the text should be by author, followed by year of publication in parentheses.

4. *References*. All papers referred to in the manuscript should be listed alphabetically by first author on a separate sheet of paper under the heading References. Each citation should be complete, consisting of author, year of publication, title of article, journal, volume, inclusive pages, and any plates or other material not paginated, according to the following example:

Birge, E. A., and Chancey Juday. 1914. A limnological study of the Finger Lakes of New York. Bull. U. S. Bur. Fish., **32**: 525–609.

For a book, list the place of publication, the publisher, and the inclusive page data.

5. Avoid excessive use of *footnotes*. Those that are necessary should be numbered consecutively and typed on a separate page following the references.

6. *Figure legends* should be typed in paragraph form on a separate page following the tables. Number the figures with arabic numerals.

Tables: Each table should be typed on a separate page following the footnotes. The descriptive title goes at the top of the page. Tables will generally be printed with a minimum of horizontal and vertical rules, and the author may indicate those he considers essential. Use arabic numerals in numbering the tables.

Illustrations: Figures will be either one column (2⅝ inches) or full page (5½ inches) in width. In planning large illustrations keep in mind the proportions of the printed page (5½ × 8⅛ inches), making due allowance for the figure legend. Lettering should be neatly done and sufficiently large so that it will be at least 1 mm high on final reduction. Blue-line graph paper is the only kind acceptable in the preparation of line cuts. Figures to be reproduced as half-tones should be submitted as glossy photographs with good contrast. Illustrations should bear the author's name and figure number, either in the margin of tracings or on the back of opaque figures. All figures larger than 8½ × 11 inches must be accompanied by page-size clear copies to be sent to the reviewers.

Proofs and reprints: Galley proofs and engraver proofs will be sent to the author directly from Allen Press, together with an order blank for reprints. The corrected proof should be returned immediately to the Editor, and the order for reprints to the Press. On orders for reprints from the authors the Society will pay half the cost of the first hundred.

Address all manuscripts and correspondence concerning editorial matters to the Editor, Kenneth M. Rae, Department of Oceanography and Meteorology, A & M College of Texas, College Station, Texas.